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New micropaleontological and palynological evidence on the stratigraphic position of the ‚German Wealden' in NW-Germany

By

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With 6 Text-figures and 2 Plates

KURZFASSUNG

Als Ergebnis mikropaläontologisch-palynologischer Untersuchungen eines relativ vollständigen Profiles der Bückeberg-Folge in Beckenfazies werden neue Hinweise für deren präzise Korrelation mit den stratigraphischen Standardskalen des Boreals und der Tethys vorgestellt. Alterszuordnungen für den obersten ‚Wealden 3' und den untersten ‚Wealden 4' sind durch Kalibrierung von Dinozysten- und Ostrakodenbefunden an der Oberrjazan-Ammonitenzonierung des Boreals und für den höheren ‚Wealden 5' und den ‚Wealden 6' an den Ammonitenzonen des (höchsten?) Untervalangins von Boreal und Tethys möglich. Aufbauend auf die jüngsten chronostratigraphischen Gliederungsvorschläge für die tethyale Unterkreide werden mit Hilfe lithologischer und palynofazieller Befunde erste Vorschläge für eine künftige Chronostratigraphie des ‚Deutschen Wealden' erläutert.

ABSTRACT

An integrated micropaleontological and palynological investigation of a fairly complete section of the Bückeberg Formation provided new evidence for its precise correlation with the Boreal and Tethyan stratigraphic standard scales. For the uppermost ‚Wealden 3' and lowermost ‚Wealden 4' a Late Ryazanian age can be assumed by calibrating dinocyst and ostracode data with the Boreal ammonite zonation. Similarly, a (Late?) Early Valanginian age is assumed for the interval from the upper ‚Wealden 5' to the top of ‚Wealden 6' by calibrating dinocyst range bases with Boreal and Tethyan ammonite zones. In the light of a new chronostratigraphic approach of the Tethyan Lower Cretaceous a preliminary sequence stratigraphic subdivision is given based on lithological and palynofacies data.

1. INTRODUCTION

The ‚German Wealden' has repeatedly been a subject of biostratigraphic investigation, in particular of micropaleontological and palynological analyses (e. g. MARTIN 1940, 1961, WICHER 1940, WOLBURG 1949, 1959, DÖRING 1965, BURGER 1966, KEMPER 1973, DORHÖFER 1977, PELZER 1982, unpubl.). Problems most commonly discussed are the biostratigraphic subdivision of the German ‚Wealden' and the position of Berriasian/Valanginian i. e. Ryazanian/Valanginian boundary within the Early Cretaceous.

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The absence of marine macrofossils, especially of ammonites, is caused by the predominantly fluvio-lacustrine to shallow lagoonal depositional environment of the ‚German Wealden' sediments. This excludes a direct calibration of the succession with the orthostratigraphic standard scales of the Boreal or Tethys Realm. A distinctive provincialism caused by the paleogeographic isolation of almost all groups of marine micro- or macrofossils which are present around the Jurassic/Cretaceous boundary makes the correlation of standard chronostratigraphic units of the Tethys and the Boreal Realm very difficult (e. g. Bartenstein 1959, Allen & Wimbledon 1991).

The sediments of the ‚German Wealden' contain agglutinated foraminifera and at some levels even calcareous foraminifera as well as rather abundant freshwater molluscs and larger plant debris. Freshwater to brackish ostracodes and palynomorphs, however, have been proven to be most suitable for a regional biostratigraphic subdivision (e. g. zonations of Wolburg 1959, Doring 1965).

In summarizing and discussing previous papers Kemper (1973) and Kemper et. al. (1978) stressed the different stratigraphic ranges covered by the English Wealden Group and the former German ‚Wealden Formation'. Consequently, the term ‚Bückeberg Formation' was introduced replacing the old term ‚Wealden Formation'. The Bückeberg Formation was subdivided into the Obernkirchen Member (lower part) and the Osterwald Member (upper part). The Osterwald Member is overlain by the marine *Platylenticeras* beds (Hilston Formation), which are commonly thought to be of Early Valanginian age in terms of the Boreal standard scale (Hoedemaeker 1987, Allen & Wimbledon 1991). Although a detailed ostracode zonal subdivision of the Bückeberg Formation exists (Kemper et al. 1978), for practical reasons the classical, well log related ‚Wolburg zonation' (Wealden 1-6) is up to now commonly used in the German oil industry. Therefore this zonation is mainly referred to in the present paper.

Previous studies have correlated the lower part of Bückeberg Formation (including its transition into the Late Jurassic) with the type Purbeck (Wessex Subbasin; compare Fig. 6). The correlation of palynological events and ostracode assemblages indicates an age equivalence of the brackish Serpulite Member with the English Cinder Beds and of the basal Bückeberg Formation (‚Wealden 1-?4') with the upper Middle or Upper Purbeck (higher Ryazanian of the Boreal stage nomenclature; compare Martin 1940, Wolburg 1959, Burger 1966, Herngreen et al. 1980).

However, no precise data are available concerning the exact position of the base of the Valanginian within the Bückeberg Formation, which is conventionally placed at the base of the Osterwald Member (base ‚Wealden 5' sensu Wolburg 1959).

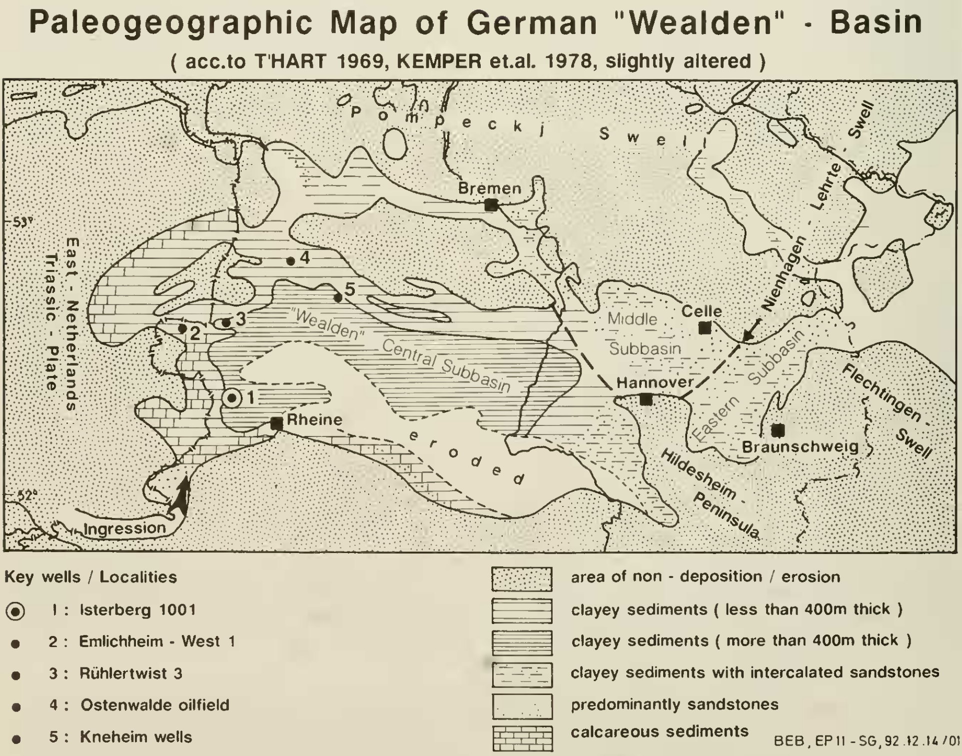

Fig. 1: Berriasian/Ryazanian palaeogeography of Northern Germany with position of well Isterberg 1001 and of other localities referred to in the text.

This problem is closely related to difficulties in correlating both Berriasian and Ryazanian stages between the Boreal region and the Tethys.

In 1980/1981 the well Isterberg 1001, situated in the western part of the central Wealden Subbasin on the flank of the Bentheim anticline (Fig. 1), cored a more than 350 m thick succession of typical lacustrine-lagoonal Wealden facies with predominantly organic rich dark shales. The organic rich shales attracted the attention of the S. C. Mineralien Erschliessungs-GmbH concerning their character as potential hydrocarbon-source rocks and as oil shale to be mined for carbonizing at low temperature. The completely cored ‚German Wealden' section of the well Isterberg 1001 provides the possibility of a multidisciplinary paleontological analysis of the Bückeberg Formation in a basinal facies. Preliminary unpublished ostracode data supplied by the above mentioned company suggested a rather complete Bückeberg Formation (‚Wealden 1-6') with transitions into the Serpulite at the base and into the *Platylenticeras* beds at the top being present.

The objective of the multidisciplinary paleontological analysis of well Isterberg 1001 was to create a palynological reference scale based on marine palynomorphs (dinoflagellate cysts) in combination with the existing local freshwater ostracode subdivision and to correlate this with Boreal (or Tethyan) ostracode or dinocyst standard zonations.

In order to obtain further evidence on the exact position of the Ryazanian/Valanginian boundary, special emphasis was paid to the investigation of the first known major marine transgression into the German Wealden Basin, which was previously described by Martin (1961) from the basal ‚Wealden 4' of the western Subbasin (Emlichheim-West 1 well, Figs. 1, 5). From this interval additional samples have been studied for calcareous nannoplankton.

In the light of a new multidisciplinary approach to Tithonian to Berriasian sequence stratigraphy in the Vocontian Trough (Jan du Chene et al., in press) a preliminary sequence stratigraphic interpretation of the studied section is given, taking into account previously published data on Wealden paleoecology (e. g. Batten 1974, 1982, Wilde & Pelzer 1987). All available lithological and paleoecological data from well Isterberg 1001 have been considered within the scope of this interpretation.

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2. PALYNOLOGY

2.1 DINOFLAGELLATE CYSTS AND OTHER PALYNOMORPHS

The core between 404.8 m and 12.4 m was sampled at an average sample interval of 2-3 m (in sum more than 200 samples). After preliminary screening, 120 samples were selected for palynological preparation and examination.

Samples were selected in priority where abundant macrofauna (principally molluscs) were reported in the core description provided by the above mentioned company. These intervals were supposed to be more favourable for dinocyst concentration. However, only a minority of slides contained significant amounts of dinoflagellate cysts (Fig. 6). The stratigraphic distribution of selected species is summarized in Fig. 2, taking into account only the dinocyst containing samples.

The palynomorph assemblages are generally of low diversity, often dominated by biostratigraphically non-diagnostic pollen and spores (e. g. bisaccate types, *Cyathidites* group, *Classopollis* spp.). Many samples are characterized by abundant highly degraded terrestrial organic matter. The state of preservation of the palynomorphs is generally poor.

The palynomorph distribution reflects a general progressive increase of marine environmental influence from the base to the top of the section. This trend can be related to a major second order transgressive trend sensu Haq et al. (1987). Marine palynomorphs (dinocysts) are restricted to relatively short intervals (flooding phases), the assemblages being often strongly dominated by very few species. These rapid marine incursions alternating with more continental conditions subdivide the major second order cycle and could thus be tentatively related to third order transgressive systems tracts (incl. maximum flooding surfaces) sensu Haq et al. (1987, see chapter 4, Fig. 6).

In the basal half of the section (404.8 m-243.5 m; Fig. 6) marine microfossils are rare, their occurrences being restricted to a few specimens at 312.2 m (upper ‚Wealden 2') and 276.1 m (lower ‚Wealden 3'). These first rare dinocysts probably appear at maximum flooding surfaces of third order transgressive events on a large coastal plain with predominant brackish to freshwater conditions.

Muderongia tabulata and *Muderongia* spp. (fragments) are the lowest recorded dinocyst species in the section (312.2 m). The range base of *M. tabulata* is related to the Calpionellids zone B at the base of Berriasian type section in the Vocontian Trough (Monteil 1991). Consequently, in terms of Boreal stage nomenclature the age of the upper ‚Wealden 2' flooding event could be as old as Latest Volgian. However, from the age assignment of overlying strata, a Ryazanian age is most likely.

At a second minor flooding phase (276.1 m) *Cantulodinium speciosum* shows its first occurrence and a first short abundance peak. A Late Ryazanian age is indicated for the lower ‚Wealden 3' flooding event, since the range base of the species corresponds to the base of *Stenomphalus* ammonite zone in the Boreal area (Costa & Davey 1991). However, the first occurrence of *Cantulodinium speciosum* doesn't seem to be properly known yet. Piasecki (1984: 147) emphasizes that „no

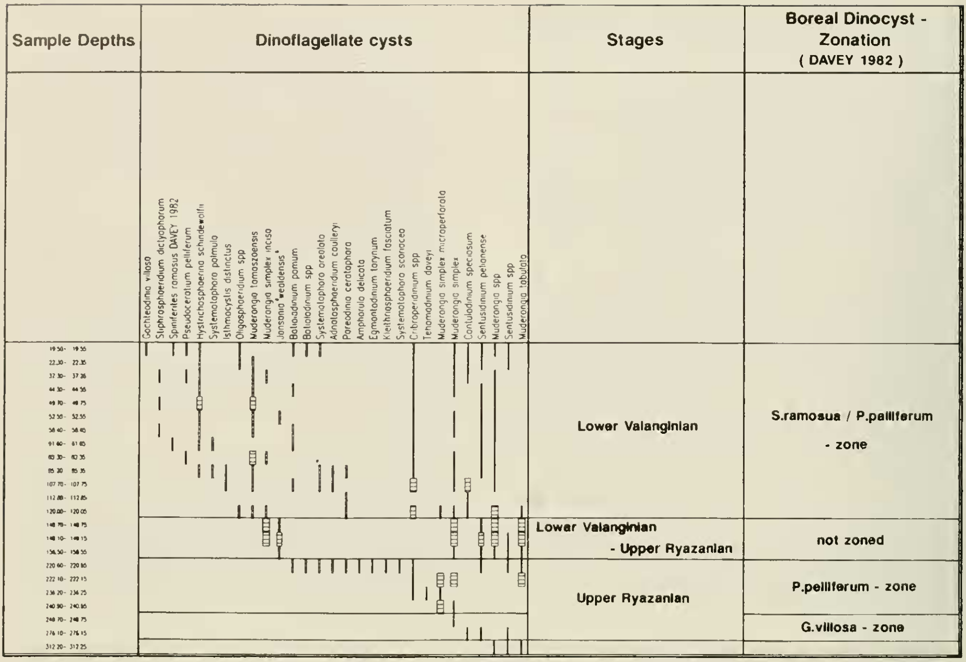

Fig. 2: Biostratigraphic distribution chart of selected dinoflagellate cyst taxa in the Isterberg 1001 well.

reports of significant numbers of *C. speciosum* have been published so far. This reflects that either the species is restricted geographically or that brackish/freshwater sediments (e. g. Purbeck-Wealden) have been neglected . . .".

Cantulodinium speciosum, found at different depths in the Isterberg 1001 core, may be an excellent index species for the German ‚Wealden Formation'. However, its range base is probably strongly determined by the second order cycle environmental succession of the section. Accordingly, it may appear significantly later in a more proximal depositional setting further to the east than in the distal western part of central Wealden Subbasin (compare record of lower flooding phases in chapter 3.1, Fig. 1).

The poor assemblages recorded in the depth interval from 276.1 m-249.7 m are vaguely correlatable to the Boreal Late Ryazanian <u>*Gochteodinia villosa* biozone</u> (*Scriniodinium pharo* subzone) of Davey (1982). This is also confirmed by further yet unpublished palynological data from other North German localities, as indicated in Fig. 5.

Most of the diversified spore associations known from the German Wealden Basin (e. g. Doring 1965, Döring et al. 1966, Dörhöfer 1979) could not be recorded in the whole section. The paleovegetation seems to have been rather uniform over large areas, microfloras being poorly diversified and strongly dominated by gymnosperms and *Classopollis* spp. Furthermore *Botryococcus* spp., prasinophytic algae and *Celyphus rallus* are regular occurring microfloral constituents, particularly within the phases of falling sea level (probably HST, chapter 4). This may confirm the setting of a large and swampy coastal plain without any significant paleomorphological differentiation and a warm humid to semiarid climate reflected by the hinterland flora (Vakhrameev 1982, Wilde & Pelzer 1987). The low hydrodynamic/energetic sedimentary setting as expressed by the lithological succession may favour the ‚in situ' alteration of abundant continental organic matter and prevent the dispersion and mixing of continental microflora.

A first major transgressive event is recorded at 240.9 m (Fig. 6) indicated by the presence of abundant *Muderongia simplex microperforata*. The rare dinocysts recorded between 237.1 m and 236.2 m may also be related to the same third order event (higher ‚Wealden 3'). Abundance peaks of *Muderongia simplex microperforata* are known from the Late Ryazanian of onshore Denmark, thus allowing a direct correlation with the Boreal <u>*Pseudoceratium pelliferum* dinocyst biozone</u> (Davey 1982). According to Costa & Davey (1991) the first appearance of *Muderongia simplex microperforata* can be dated within the Boreal <u>*Stenomphalus* ammonite zone</u>. The presence of rare *Tehamadinium daveyi* at 236.2 m confirms the age dating of this flooding phase within a Late Ryazanian to Earliest Valanginian interval.

An important dinoflagellate cyst abundance and diversity peak is recorded between 222.1 m and 220.6 m (base ‚Wealden 4'). At this interval microfloras are strongly dominated by *Muderongia simplex*, *Muderongia tabulata* and *Muderongia simplex microperforata* restricting the assemblages to a Late Ryazanian age. Other species recorded at this depth partly supporting the age assignment are: *Egmontodinium torynum*, *Kleithriasphaeridium fasciatum, Batioladinium* spp., *Amphorula delicata, Pareodinia ceratophora, Systematophora scoriacea* and *Sentusidinium* spp.

The interval from 211.3 m to 162.1 m contains no diagnostic palynomorphs, comprising frequently barren samples with abundant terrestrially derived, highly biodegraded, dull to non-fluorescent organic matter (up to structureless and ‚fluffy' disperse material). As mentioned above, this palynofacies type is certainly related to shallow, restricted environmental conditions with in situ (?microbial) alteration of organic matter. Although probably no lowstand deposits are present in the whole Wealden section, the degradation processes, which have affected the organic matter, might be similar to those which have produced the large quantities of structureless terrestrial material within the Late Tithonian to Berriasian deep marine lowstand wedges of the Vocontian Trough (Gorin & Steffen 1991).

This interval is overlain by another obvious marine transgression between 156.5 m and 148.7 m (around the base of ‚Wealden 5', probably corresponding to the base of the Osterwald Member of the Bückeberg Formation). The assemblages with dinocyst diversity and abundance peaks are characterized by the dominance of *Muderongia simplex* and *Muderongia tabulata*. Other commonly occurring taxa are a yet undescribed species with a morphology close to *Jansonia* (tentatively named *‚Jansonia wealdensis'* in Fig. 2) and *Sentusidinium* spp.

The overlying interval is again somewhat poorer and non diagnostic (145.5 m to 121.7 m), and is essentially dominated by bisaccate pollen types. In a few samples *Celyphus rallus* and *Botryococcus* spp., mostly associated with biodegraded terrestrial organic matter, are also found.

Some very important age diagnostic dinocyst taxa have their first occurrences in the uppermost, very distinct and thick transgressive interval, spanning a section including uppermost ‚Wealden 5' and ‚Wealden 6' from 120.0 m to the top of the investigated profile (18.2 m; Fig. 6). The most significant first occurrences within this very rich interval are *Muderongia tomaszoensis* and *Oligosphaeridium* spp. at 120.0 m and *Hystrichosphaerina schindewolfii* at 85.3 m. The range base of *Muderongia tomaszoensis* is known from the *Pertransians* ammonite zone (late Lower Valanginian) of the Tethys type sections (Monteil 1991). According to Costa & Davey (1991) the base occurrence of *Hystrichosphaerina schindewolfii* is located at the base of the *Paratollia* ammonite zone (Lower Valanginian of the Boreal Realm). The assemblages, recorded in the thick uppermost transgressive interval, correspond roughly to the Boreal *Spiniferites ramosus/Pseudoceratium pelliferum* dinocyst biozone of Davey (1982). All calibrations are concordant to indicate a (?Late) Lower Valanginian age for the uppermost part of the Isterberg 1001 core.

A succession of several third order cycles may occur within the 120.0 m-18.2 m interval. However, their recognition by palynofacies trends or by a succession of abundance and/or diversity peaks of dinocyst assemblages is obscured by a general increasing marine environment related to a probably second order transgressive trend sensu Haq et al. (1987).

3. MICROPALEONTOLOGY

3.1 OSTRACODA AND FORAMINIFERA

Only the middle part of the Isterberg core (240 m-205 m, Fig. 6) has been closely sampled for examination of microfauna. The objective was to get detailed information on the first major transgressive phase around the ‚Wealden 3'/‚Wealden 4' transition (Obernkirchen Member) described by Martin (1961) from the well Emlichheim West 1. A semi-quantitative range chart of this interval is given in Fig. 3. From the remaining part of the section, only a few samples have been examined for ostracodes and other microfauna in order to control the preliminary ostracode-based stratigraphic subdivision (‚Wealden 1-6' sensu Wolburg 1959).

In the predominantly fluvio-lacustrine to shallow lagoonal Bückeberg Formation, several marine flooding phases are known to occur (chapter 2). These flooding phases could be easily recorded by microfauna in the central Wealden Subbasin (Fig. 1), becoming less distinct towards the middle and eastern Subbasin, where progressively prograding fluvio-deltaic sands dominate the highly variable lithologic spectrum. The increasing amount of sphaerosiderite, probably in consequence of partly anoxic environments in the middle and eastern Subbasin, is connected with poor or even lacking microfaunas.

Two earlier, less distinctive flooding events below the above mentioned first major flooding phase (appearance of *Pachycytheridea compacta*) at the base of ‚Wealden 4', restricted to the lower Obernkirchen Member of the central Wealden Subbasin, could be recognized. They are indicated by the appearance of *Macrodentina mediostricta transfuga* and *Galliaecytheridea postsinuata* in the uppermost ‚Wealden 2' and by the occurrence of *Cytheropteron impressum* within ‚Wealden 3'. Both flooding events could be recorded in the well by the occurrence of sparse dinoflagellate cyst assemblages (chapter 2).

The sediments of the base ‚Wealden 4' flooding phase, containing a significant proportion of marine microfauna, can be traced over the whole German Wealden Basin up to the Gifhorn Trough. Although abundance and diversity of marine assemblages decreases towards the eastern Subbasin, an age-equivalent microfauna has been observed even in the area east of Hannover within a distinct dark grey shale horizon (‚Dunkelgraue Tonsteinbank', Roll 1971).

The age equivalence of the marine microfauna described by Martin (1961) from a core of well Emlichheim West 1 (Fig. 1, 5) with the above mentioned base ‚Wealden 4' flooding phase in the well Isterberg 1001 is evident from log correlation and comparison of microfaunas (Fig. 5).

Although no geophysical and electrical logs exist for well Isterberg 1001 which might support the discrimination of

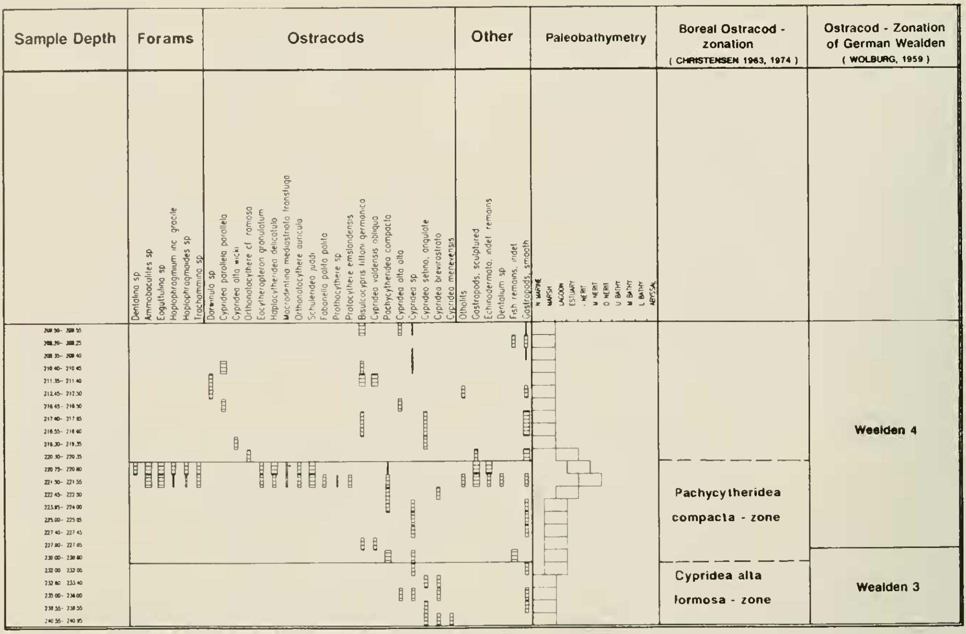

Fig. 3: Biostratigraphic distribution chart of selected foraminifer- and ostracode taxa in the Isterberg 1001 well.

lithological units, parasequences and systems tracts, the base ‚Wealden 4' flooding event could be precisely located by means of a first preliminary micropaleontological survey analysis around the ‚Wealden 3-4' transition.

A subsequent detailed analysis of the flooding interval yielded a very rich and rather diverse microfauna. A two phase flooding event (marine microfaunas at 220.8 m and 221.5 m), bounded and interrupted by sediments with brackish-lagoonal assemblages (230.9 m-222.45m; 221.3 m; 220.3 m; *Pachycytheridea compacta* zone, CHRISTENSEN 1963, 1974; Figs. 4-6) were observed. The microfaunas of both marine intervals are characterized by abundant echinoderm fragments, sculptured gastropods and otoliths, and particularly by common to abundant occurrence of the following ostracode and foraminifera taxa: *Stravia crossata* (syn. *Haplocytheridea delicatula*), *Schuleridea juddi* (very abundant), *Macrodentina mediostricta transfuga*, *Orthonotacythere auricula*, *Cytheropterina triebeli* (syn. *Eocytheropteron granulatum*), *Haplophragmoides* sp., *Trochammina* sp., *Ammobaculites* sp. and *Eoguttulina* sp..

The lower marine assemblage (221.5 m) is additionally characterized by the common appearance of *Protocythere emslandensis* and *Dentalium* sp. and by specimens of *Fabanella polita polita* and *Orthonotacythere* cf. *rimosa*, whereas in the upper assemblage (220.8 m) rare examples of *Haplophragmium inconstans gracile* could be recorded.

Within the brackish-lagoonal communities non-sculptured gastropods and ostracodes of the genera *Pachycytheridea* and *Cypridea* are dominant (Figs. 4, 5). Both above and below the flooding interval (230.9 m-220.3 m) *Pachycytheridea compacta*

Plate 1

Fig. 1, 2 *Muderongia simplex microperforata* DAVEY. - Specimens with apical operculum detached, corroded cyst wall, sample 240.90 m-240.95 m, (upper ‚Wealden 3'), Transmittant White Light (TWL), magnification approx. 500 x.

Fig. 3, 6 *Muderongia tomaszoensis* ALBERTI. - Specimen in dorsoventral view with operculum in situ, sample 82.30 m-82.35 m (basal ‚Wealden 6'); Fig. 3: Interference Phase Contrast (IPC), 500 x, Fig. 6: TWL, 500 x.

Fig. 4, 7 *Muderongia simplex*-type with incised lateral horns (tentatively named ‚*Muderongia simplex incisa*' in Fig. 2). - Specimen in Fig. 7 with detached apical operculum, Fig. 4: sample 148.70 m-148.75 m, TWL, 500 x; Fig. 7: sample 149.10 m-149.15 m, IPC, 500 x, both samples basal ‚Wealden 5'.

Fig. 5 *Muderongia tomaszoensis* ALBERTI. - Operculum detached, sample 82.30 m - 82.35 m (basal ‚Wealden 6'), IPC, 780 x.

Fig. 8, 9 *Cantulodinium speciosum* ALBERTI. - Fig. 8: left lateral view, TWL, 750 x; Fig. 9: dorsoventral view, IPC, 780 x; both specimens sample 107.70 m -107.75 m (topmost ‚Wealden 5').

Fig. 10 *Pseudoceratium pelliferum* GOCHT. - Short horned form, apical operculum detached, sample 107.70 m-107.75 m (topmost ‚Wealden 5'), IPC, 780 x.

Fig. 11 *Batioladinium pomum* DAVEY. - Dorsoventral view, sample 54.50 m -54.55 m (‚Wealden 6'), TWL, 780 x.

Fig. 12 *Batioladinium* sp. I DAVEY, 1982. - Damaged specimen with detached operculum, sample 54.50 m-54.55 m (‚Wealden 6'), TWL, 780 x.

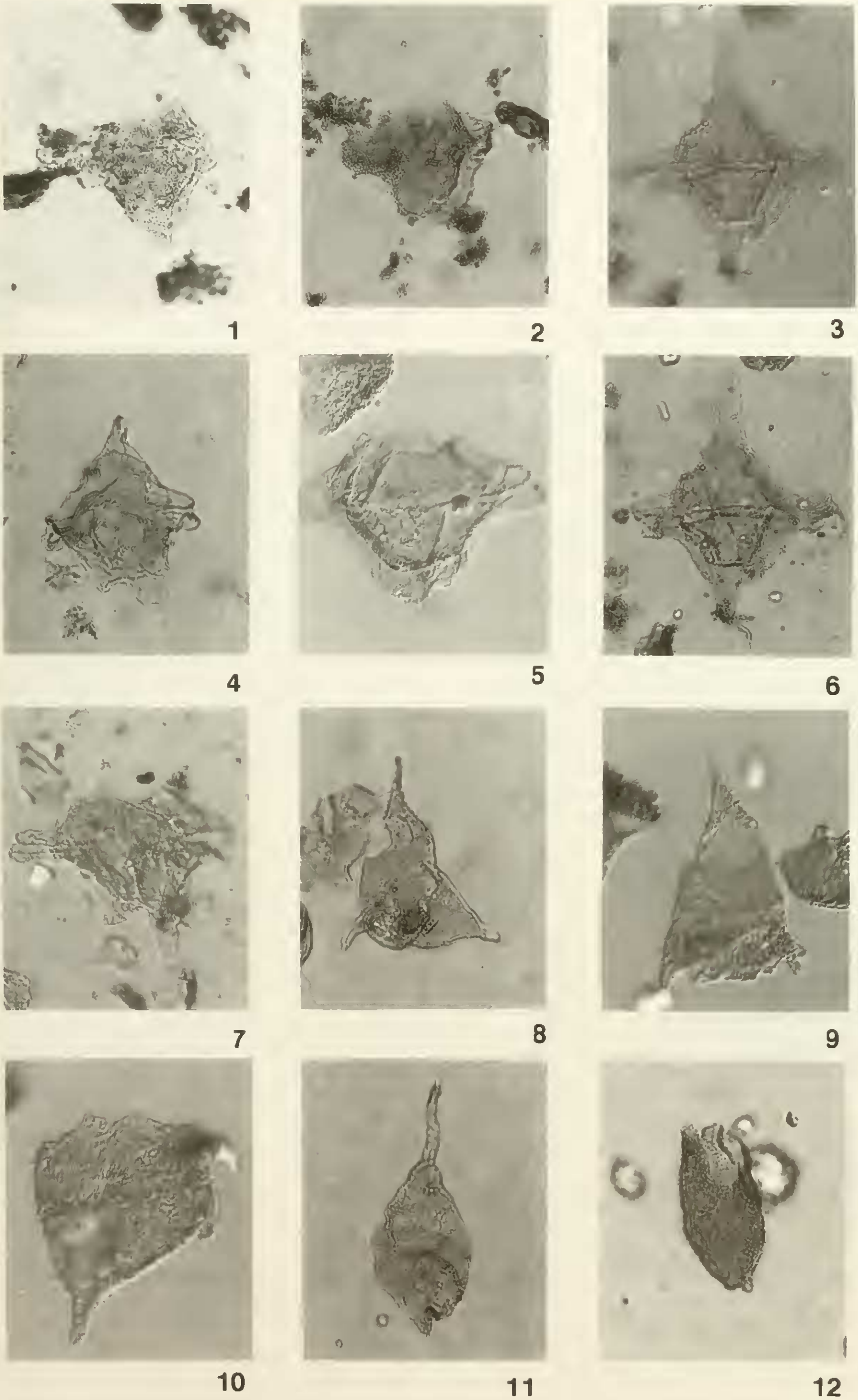

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Plate 1

and the angulate type of *Cypridea setina* are commonly present. Additionally the following species are found: From above the marine assemblages *Cypridea alta alta, Cypridea alta wicki, Cypridea parallela parallela, Cypridea valdensis obliqua* and *Bisulcocypris fittoni germanica* and from below the marine assemblages: *Cypridea brevirostrata*.

At least some of the ostracode species are considered to be of stratigraphic importance, whereas the foraminifera species are mainly evidence for the marine (inner neritic) paleo-environment of the base ‚Wealden 4' flooding phase. *Macrodentina mediostricta transfuga, Orthonotacythere auricula, Orthonotacythere* cf. *rimosa* and *Fabanella polita polita* are so far only known from the Bückeberg Formation. The first appearance of *Stravia crossata* (syn. *Haplocytheridea delicatula* and *Haplocytheridea nana* in BARTENSTEIN & BRAND 1951) within the base ‚Wealden 4' flooding phase is a consistent marker event all over the German Wealden Basin.

The marine base ‚Wealden 4' microfauna is most closely comparable to an assemblage with abundant *Schuleridea juddi* and *Cytheropterina triebeli* (Speeton D 6 level) from the type locality of Speeton Clay described by NEALE (1962a: tab. 7). Since the Speeton type locality is dated by ammonites (*albidum* zone, NEALE 1962 b, RAWSON & RILEY 1982), an indirect stratigraphic calibration of the base ‚Wealden 4' flooding phase with the Upper Ryazanian of the Boreal stage nomenclature can be derived (referred to as ‚Berriasian' in NEALE 1962 a and ‚Ober-Berrias' in KEUPP & MUTTERLOSE 1984).

Another indirect calibration with the Boreal subdivision can be derived from the comparison of the interval with *Pachycytheridea compacta* WOLBURG in the uppermost ‚Wealden 3' and lower ‚Wealden 4' with the *Pachycytheridea compacta* zone from the Jydegard Formation of Bornholm (CHRISTENSEN 1963, 1974). This interval is dated as Upper Ryazanian to Lower Valanginian by means of dinoflagellate cysts (PIASECKI 1984, chapter 2).

As for calibration of German ‚Wealden Formation' in the Isterberg 1001 well with the Berriasian and Valanginian stratotypes of the Tethys area, the evidence within the microfauna is almost neglectable (e. g. BARTENSTEIN 1962). According to OERTLI (1966) *Protocythere emslandensis*, first occurring at the base ‚Wealden 4' in the German ‚Wealden Formation', has a first appearance within the Lower Valanginian stratotype section of Swiss folded Jura Mountains.

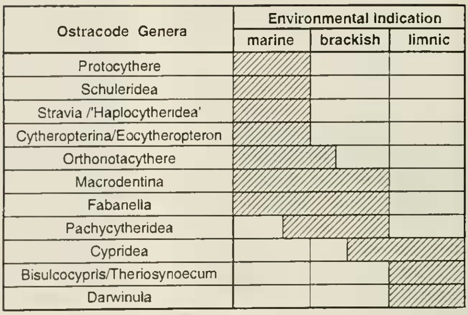


Fig. 4: Palaeoenvironmental indications of selected ostracode genera of the Bückeberg Formation in Northern Germany

3.2 CALCAREOUS NANNOPLANKTON

45 samples were analysed for calcareous nannoplankton from the section around the ‚Wealden 3/4' transition (240.0 m - 219.4 m). Unfortunately, most of the samples turned out to be barren; only few yielded very impoverished and monotypic assemblages (220.7 m; 225.2 m; 227.5 m; 229.5 m; 230.6 m; 232.1 m; 232.5 m and 233.1 m with only *Watznaueria barnesae* being present), supporting the general brackish paleoenvironment of the *Pachycytheridea compacta* zone.

The interval from 221.75 m to 221.5 m yields a slightly more diverse nannoflora. *Zygodiscus diplogrammus, Rhagodiscus asper, Micrantholithus obtusus* and *Parhabdolithus embergeri* were observed in five samples, indicating the most intense marine influx for this interval. The remainder of the samples investigated is essentially barren. No age diagnostic species were observed.

The nearly monospecific assemblages might suggest a selection due to dissolution. In particular *W. barnesae* dominated assemblages are indicators of dissolution (ROTH & KRUMBACH 1986). However, this influence is not supported by the generally high calcium carbonate content (221.8 m: 58.5 %; 221.7 m: 28.2 %; 221.65 m: 35.6 %; 221.50 m: 5.6 %; 221.4 m: 9.7 %). Furthermore *W. barnesae*, an ecologically robust species, is never dominating in anyone of the samples (only one or two specimens of each species discussed were observed in the samples).

Plate 2

Fig. 1 *Stiphrosphaeridium dictyophorum* (COOKSON & EISENACK) DAVEY. - Ventral focus, apical operculum detached, sample 37.30 m-37.35 m (‚Wealden 6'), IPC, 780 x.

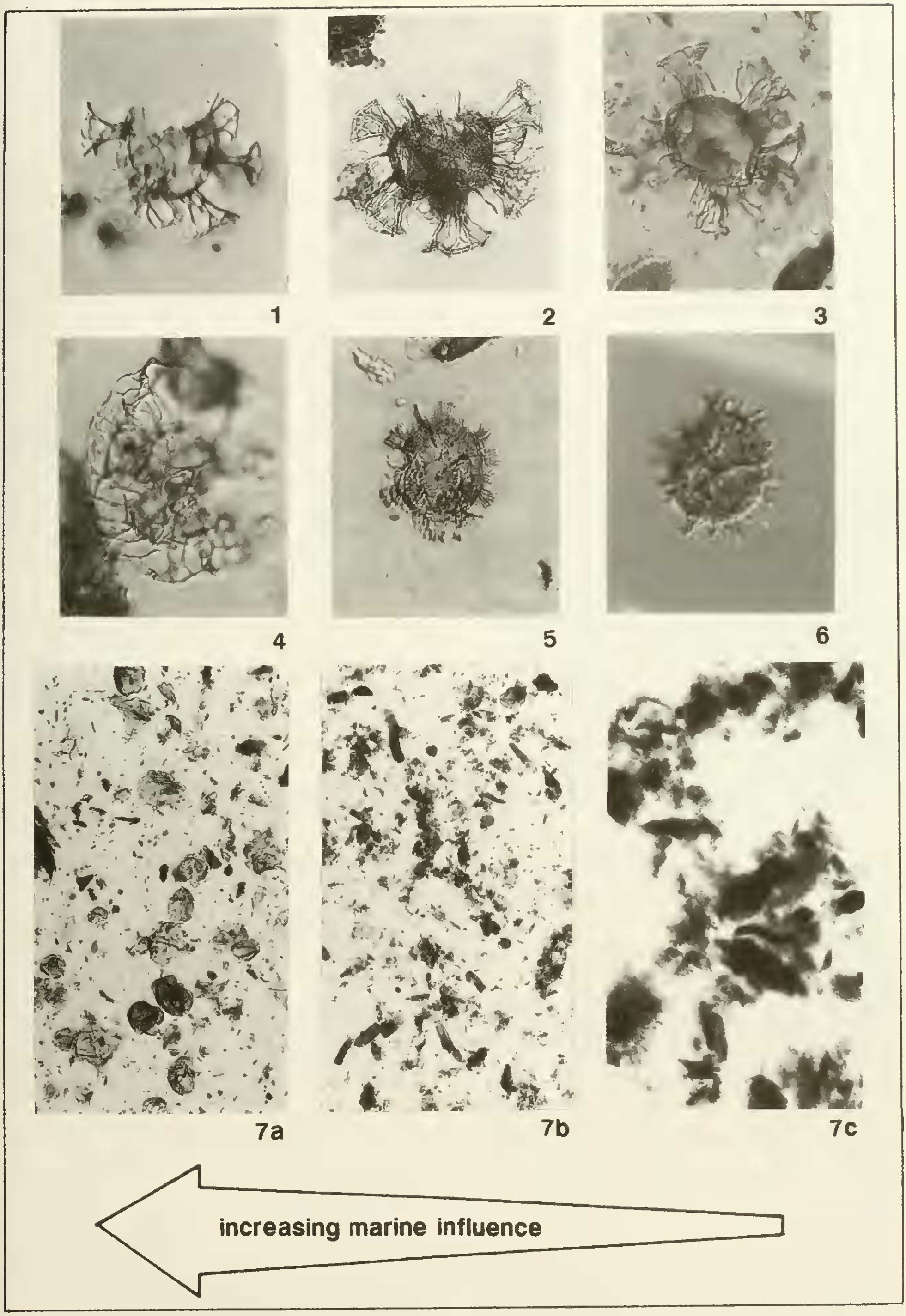
Fig. 2, 3 *Hystrichosphaerina schindewolfii* ALBERTI. - Fig. 2: dorsoventral view, sample 49.70 m-49.75 m (‚Wealden 6'), TWL, 780 x; Fig. 3: apical focus, sample 54.50 m-54.55 m (‚Wealden 6'), IPC, 780 x.

Fig. 4 *Adnatosphaeridium caulleryi* (DEFLANDRE & COOKSON) WILLIAMS & DOWNIE. - Damaged specimen in oblique dorsal focus, sample 220.60 m-220.65 m (basal ‚Wealden 4'), IPC, 780 x.

Fig. 5 *Kleithriasphaeridium fasciatum* (DAVEY & WILLIAMS) DAVEY. - Dorsoventral view, sample 220.60 m-220.65 m (basal ‚Wealden 4'), TWL, 780 x.

Fig. 6 *Spiniferites ramosus* group sensu DAVEY 1982. - Lateral view, sample 61.60 m-61.65 m (‚Wealden 6'), IPC, 780 x.

Fig. 7 Palynofacies response to third order flooding events (magnification apprx. 200 x). Fig. 7 a: (fluvio-lacustrine environments, HST, ?LST) - large biodegraded lumps of terrestrial organic matter with occasionally preserved cell structure predominating. Fig. 7 b: (transitional brackish environments, TST) - abundant small to medium sized organic matter with pioneering blue green alga Celyphus rallus; Fig. 7 c: (shallow marine environments, mfs equivalents) - predominating *Muderongia* spp. and other marine and terrestrial palynomorphs.


1
2
3
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5
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7a
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7c
increasing marine influence

Thus it seems more likely that calcareous nannofossils are in general ecologically more sensitive than foraminifera and dinocysts. The nannofloras were only able to settle restricted shallow water settings once paleoceanographic conditions were most suitable. Obviously nannofloras can not tolerate stress environments. This pattern is supported by the absence of calcareous nannofossils from the Early Valanginian of the NW-German Basin and from Speeton (MUTTERLOSE 1992).

4. CONCLUSIONS

The well Isterberg 1001 recovered a fairly complete section of the Bückeberg Formation (‚German Wealden') and provides evidence for its precise calibration with the Boreal (and Tethyan) stratigraphic standard scales.

Direct biostratigraphic calibration indicators are summarized in Fig. 6. For the uppermost ‚Wealden 3' and lowermost ‚Wealden 4' a Late Ryazanian age is supported by the calibration of dinocyst and ostracode data with the Boreal ammonite zonation. A (?Late) Early Valanginian age is evident for at least the interval from uppermost ‚Wealden 5' to the top of ‚Wealden 6' (higher Osterwald Member) by calibration of characteristic dinocyst range bases with Boreal and Tethyan ammonite zones. Thus, the Ryazanian (Berriasian)/Valanginian boundary can be placed somewhere in between the upper ‚Wealden 4' to lower ‚Wealden 5' (compare Chapter 1).

The above described cyclic changes of palynofacies types from ‚clean' assemblages dominated by marine and terrestrial palynomorphs (dinocyst abundance and diversity peaks) to ‚dirty' assemblages with abundant degraded organic matter (up to disperse ‚fluffy' material) and with higher quantities of *Celyphus rallus* (a pioneering blue-green algal species adapted to brackish to freshwater transitional environments according to BATTEN & VAN GEEL 1985) and *Botryococcus* sp. are interpreted to reflect third order eustatic sea level fluctuations sensu HAQ et al. (1987). A second order transgressive trend is superimposed on the third order cyclicity, and is clearly reflected by a general increasing dinocyst diversity from at least the lower ‚Wealden 4' upwards (Fig. 6).

A third order cyclicity is also clearly reflected by characteristic changes of predominating lithotypes (see WIESNER 1983). A cyclic sedimentological succession of dark, organic rich fissile claystone (‚claystone I', Fig. 6), subfissile dark grey to black claystone (‚claystone II') and lighter grey claystone rich in gastropods and bivalves with frequently intercalated shell layers (‚claystone III') is interpreted to reflect higher order eustatic sea level fluctuations. In the overall relatively proximal depositional setting of the Bückeberg Formation LST equivalents are probably mostly lacking. Accordingly, transgressive sediments, reflected by claystone III-type sediments with interspersed shell layers, are overlying directly the HST equivalents (claytone I and II) with sharp, erosive basis contacts (WIESNER 1983).

The second order transgressive trend explained above is reflected in the increasing relative proportion of claystone III in the overall lithological column. A relatively sharp facies change with respect to palynology (above 120.0 m) and lithology (between 110 and 120 m, Fig. 6) may be related to a second order transgressive surface of uppermost Lower Valanginian, recorded from just above the *Pertransiens* ammonite zone within the overlying *Campylotoxum* ammonite zone of the Tethyan type areas (JACQUIN, oral comm., HAQ et al. 1987). This interpretation would be largely in

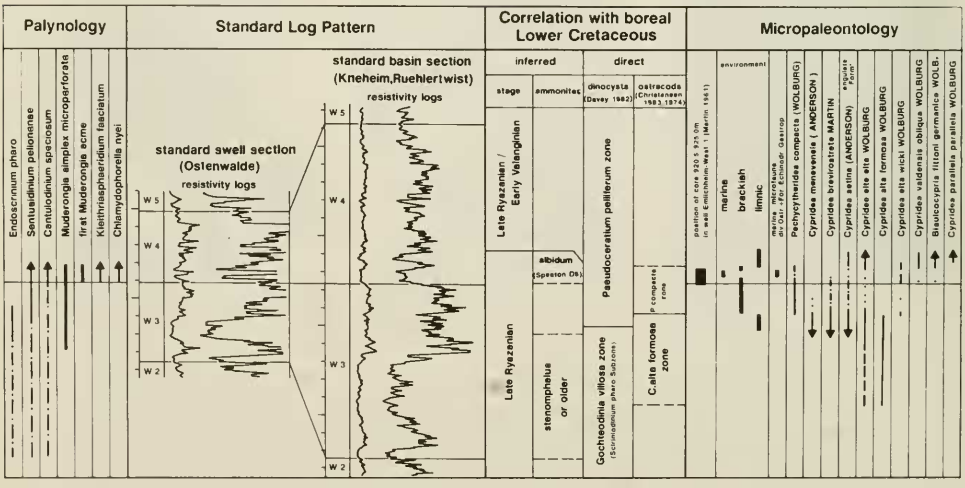

Fig. 5: Integrated correlation chart of bio- and logstratigraphical indications of ‚Wealden 3' and lower ‚Wealden 4' transgression phases as recorded in basin and swell profiles of the central Wealden Subbasin.

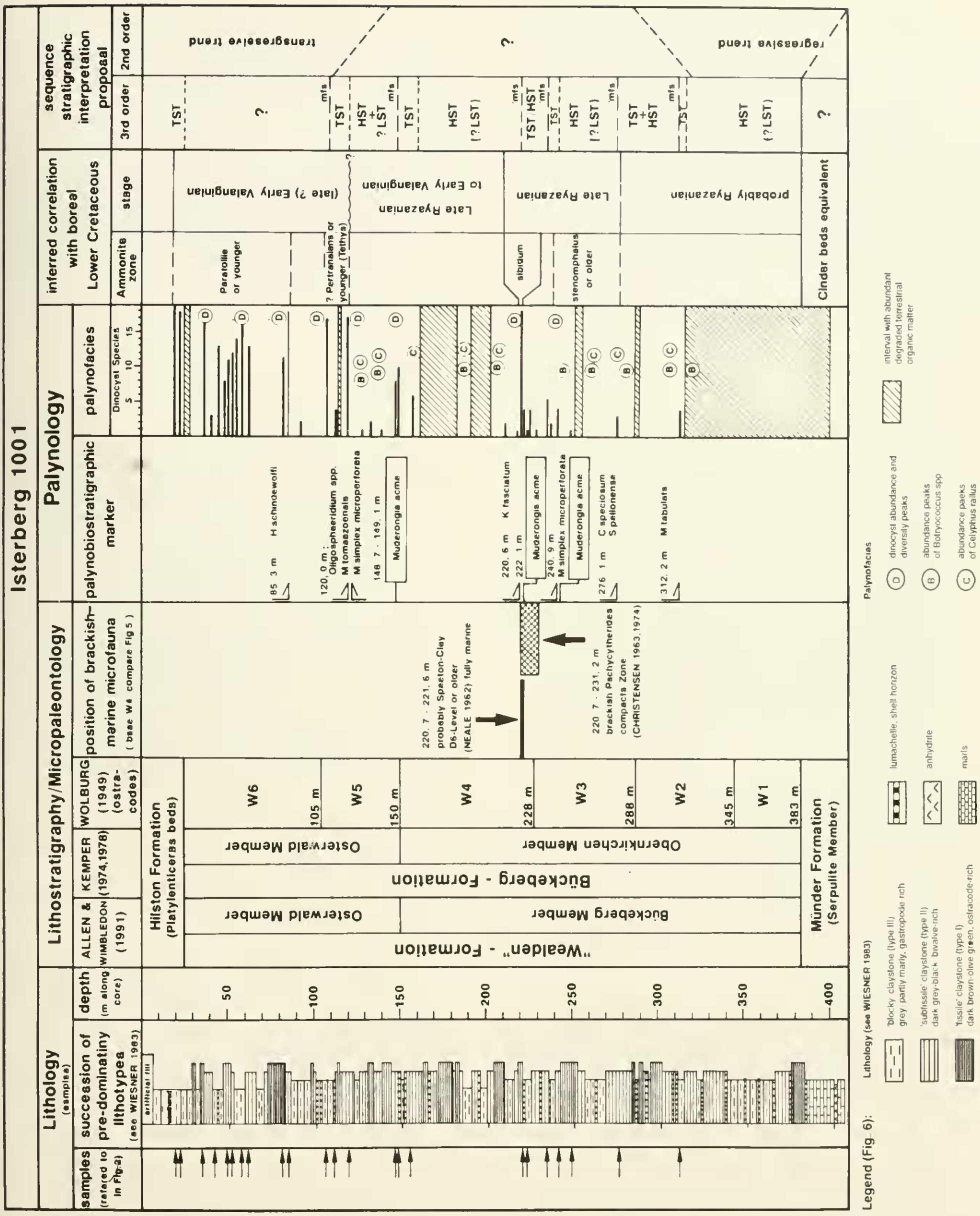

Fig. 6: Summary chart: lithology/lithostratigraphy, biostratigraphy, palynofacies and sequence stratigraphy of well Isterberg 1001.

concordance with the biostratigraphic indications mentioned above and would theoretically imply the possibility of Lower Valanginian (Upper Ryazanian) being at least partly eroded.

The lowermost part of the Isterberg 1001 section is thought to represent a second order regressive trend from the shallow marine Serpulite Member (which is commonly paralleled with the English Cinder Beds) towards the mainly fluvio-lacustrine lower ‚Wealden 3', which is most clearly reflected by the successive lithological change from marly, partly anhydritic sedimentation over distinct blocky claystones with abundant shell layers towards more fissile, dark and organic rich shales. The general poor palynomorph content of this interval probably partly caused by somewhat hypersalinar conditions prevent the discrimination of further higher order (palynofacies) cycles being possibly present.

In the light of the novel multidisciplinary approach on Tithonian to Berriasian sequence stratigraphy in the type sections from the Vocontian Trough (Tethys; e. g. JAN DU CHENE et al., in press) the possibility to discriminate and calibrate several higher order cycles within the Bückeberg Formation opens future prospects concerning its detailed chronostratigraphic subdivision and, accordingly, new options for calibration with the Lower Cretaceous Tethyan standard scale.

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